VC Investment into Thin Film Solar Photovoltaics – where is it going and why?

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ABSTRACT

The large scale adoption of solar photovoltaics (PV) depends largely on its ability to achieve cost of delivering electric power, cost per watt, comparable to that of conventional energy sources, and being able to do so with high conversion efficiencies. Among the different solar PV technologies, thin film PV technologies stand out as candidates likely to achieve these two objectives in the near term. We compare the three promising thin film PV technologies – Amorphous Silicon (a-Si), Cadmium Telluride (CdTe), and Copper Indium Gallium Selenium (CIGS) along these two dimensions, cost per watt and conversion efficiency. We then compare them against the total VC investment flowing into these three technologies. The VC investment seems to be guided by the prospect of high conversion efficiency more than low cost per watt. We offer possible explanations for this behavior.

I. INTRODUCTION

The solar PV industry is poised for a period of tremendous growth[1]. Although the cost of delivering a unit of electric power, cost per watt, is currently higher for PV modules when compared with conventional energy sources, innovations in the PV technology are expected to drive PV to cost parity with conventional energy sources in the coming years[2]. In addition to cost, another important consideration is the amount of electric power that can generated from a given amount of incident sunlight, called the conversion efficiency. This is an important consideration for large scale adoption because high conversion efficiency means that the solar cell itself will be of a small physical size, an important consideration for many applications of solar PV[3].

The currently popular technology, crystalline silicon (c-Si) has a high conversion efficiency but a high cost per watt as well because the material used, crystalline silicon, is expensive. A group of new technologies, collectively labeled thin film technologies, offer much lower cost per watt primarily because they use less expensive materials than crystalline silicon. Although thin film technologies currently have lower efficiencies when compared to c-Si, new innovations to these technologies are expected to increase the efficiency. Thin film solar panels have the additional advantage that they can be made with flexible substrate materials like plastics, which makes it easy for them to be integrated into windows and roofs, an important consideration for successful commercialization of solar PV cells[4].

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1 *See* Steve O'Rourke, et al., *Solar Photovoltaics: SEMI - Industry Strategy Symposium*, DEUTSCHE BANK SECURITIES REPORT (2008).

2 *See* Ken Zweibel, *Issues in Thin Film PV Manufacturing Cost Reduction*, 59 SOLAR ENERGY MATERIALS & SOLAR CELLS (1999).

3 *See* Wilfried van Sark, et al., *Analysis of the Silicon Market: Will Thin Films Profit?*, 10 ENERGY POLICY (2007).

4 *See* Rommel Noufi, et al., *High-Efficiency CdTe and CIGS Thin-Film Solar Cells: Highlights and Challenges*, NATIONAL RENEWABLE ENERGY LABORATORY (2005).

Hence these technologies have generated considerable interest in the solar industry. Thin film solar grew from 5.8% to 7.5% of worldwide solar-electric equipment production in 2006 alone and is expected to grow to ~20 percent of the market share by 2010[5]. Amorphous Silicon (a-Si), Cadmium Telluride (CdTe), and Copper Indium Gallium Selenium (CIGS) are the leading thin film technologies in efficiency and cost per watt. An important question that arises in this context is which if these three candidates would be most likely to garner most of the solar PV market, and why?

II. METHODOLOGY

We take a first stab at this question, by comparing the efficiencies and cost per watt of these three technologies. We then look at the flow of Venture Capital (VC) investment into these three technologies and use the VC investment as a tool to identify which technology has the potential of being most successful. Our assumption here is that the decisions of the VCs are the right ones, i.e. they have full knowledge of the relative merits and possibility of success of these technologies. While this is not fully correct, we believe that VCs probably have the best knowledge of the probability of market success of these technologies. The time period of our study is January 2004-December 2008.

III. DATA

The data for this paper was obtained from National Renewable Energy Laboratory (NREL) press releases and reports, Deutsch Bank and other active financial intermediaries' solar industry analysis and forecasts, trade journals and technical magazines, and academic journals including the *Thin Solid Films* and *Solar Energy Materials and Solar Cells*. We summarize our data in the following graphs. Figure 1 shows the best research cell conversion efficiencies for the three technologies, verified by NREL[6]. Cell efficiencies have not improved for CdTe and a-Si technologies since 2004 whereas they have consistently increased each year for CIGS. The cell efficiency of CIGS in end 2008 was 20%, ahead of the 16% achieved by CdTe.

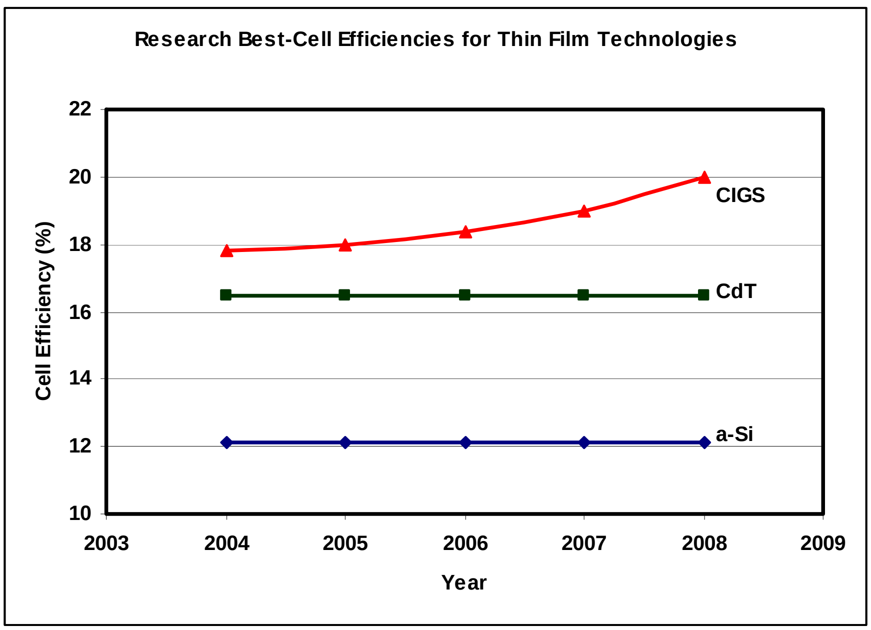

Figure 1

Notes: CIGS consistently has the best research cell efficiency, which moreover has been improving over time.

However, for commercial applications solar cells are rarely used individually. May solar cells are put together in a

[5] *See* Kenji Yamamoto, et al., *Cost Effective and High-Performance Thin Film Si Solar Cell Towards the 21st Century*, 66 SOLAR ENERGY MATERIALS & SOLAR CELLS (2001).

[6] *See* Larry Kazmerski, et al., *Best Research-Cell Efficiencies*, NATIONAL RENEWABLE ENERGY LABORATORY (2009).

module which can generate the appropriate voltages and currents needed for different applications. The conversion efficiency of the modules might be different from those of individual cells. Figure 2 shows the module efficiencies for the three technologies, verified by NREL[7]. CIGS has consistently had a higher module efficiency than both a-Si and CdTe for all years in 2004-2008.

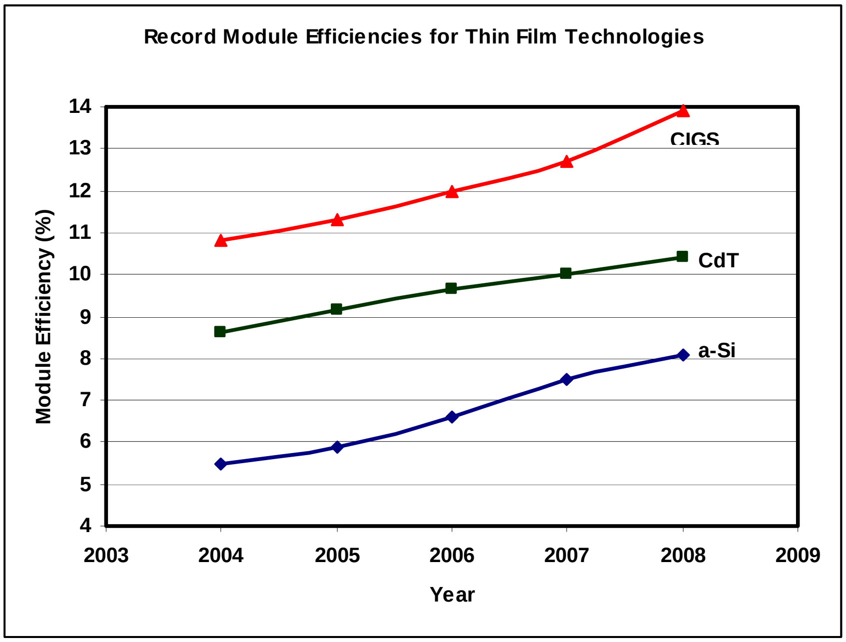

Figure 2

Notes: CIGS has consistently had the highest module efficiencies.

Figure 3 shows the VC investment into the three technologies[8][9]**.** It is clear from the graph that VCs favor CIGS as the technology of choice and investment into CIGS far outruns even the combined investment into CdTe and a-Si.

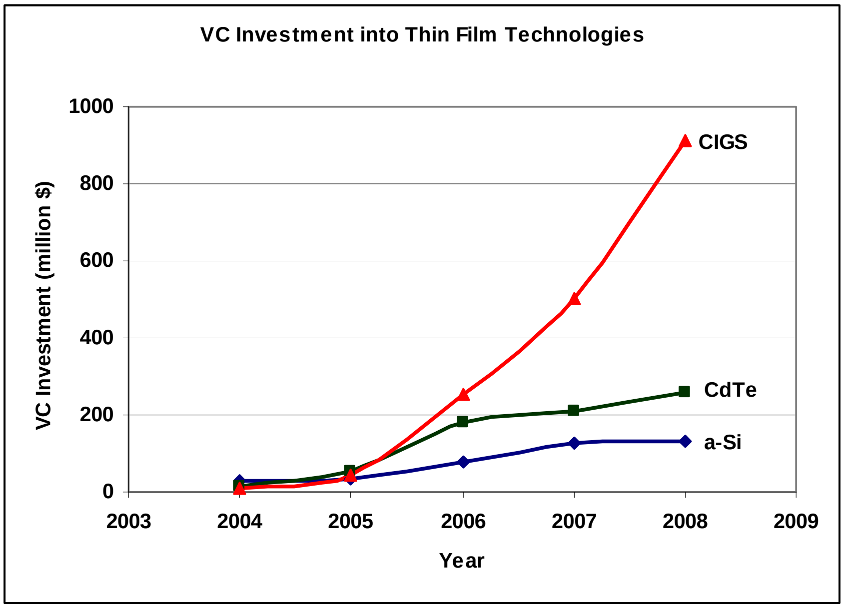

Figure 3

[7] *See* Ken Zweibel, et al., *Record Module Efficiencies*, NATIONAL RENEWABLE ENERGY LABORATORY (2009).

[8] *See* Hari Polavarapu, *Solar Photovoltaics*, DEUTSCHE BANK SECURITIES REPORT (2007).

[9] *See* Steve O'Rourke, et al., *Solar Photovoltaics: SEMI - Industry Strategy Symposium*, DEUTSCHE BANK SECURITIES REPORT (2008).

Notes: VC investment into CIGS is very high when compared to CdTe and a-Si.

IV. DISCUSSION

It is clear from Figure 3 that VCs view CIGS as the most promising technology. The VC investment into CIGS in 2008 is more than the combined investment into a-Si and CdTe. This happens despite the fact the CdTe has current cost per watt lower than CIGS. The cost per watt for CIGS is $2.00, much higher than the $0.98 for CdTe or $1.65 for a-Si[10]. In spite of being the more expensive technology currently, and being expected to remain so in the future, VCs favor investing in CIGS more than in the other two technologies. One explanation for this behavior is that continuing improvements in efficiency of CIGS cells would by itself lower the cost per watt and make CIGS cost competitive with CdTe and a-Si in the near future. However, there is no clear consensus on this and many studies of thin film photovoltaic technologies project that CIGS will remain the more expensive technology even as far as 2020[11]. An alternative explanation is that VCs view efficiency as the more important factor in determining the technology's success, even more than cost per watt. As Figures 2 and 3 show, the efficiency of CIGS is currently higher than CdTe and a-Si, both at the cell and the module level.

If efficiency considerations are indeed the reason, it raises the question - why do VCs think higher efficiencies are more important than lower cost per watt? We offer some tentative explanations here. First, a higher efficiency means that the solar cell can be of a smaller size. Smaller size gives two advantages - the solar cell occupies less space in the house, whether on the roofs or the windows, and the cell will be lighter, making it easier to the supported by most common type of residential and commercial roofs[12]. A heavy cell will need additional expensive roof work to be done to be able to support it. Second, it could be that VCs expect the cost per watt of CIGS to come down more than is currently expected. As is well known, there are huge economies of scale in the solar cell industry[13]. The high cost per watt of CIGS currently might come down significantly when the economies of scale kick in as more production is done with CIGS technology. If CIGS do achieve comparable cost per watt to CdTe, it is likely that the higher efficiency of CIGS will push it forward as the dominant technology.

Could there be reasons other than high efficiencies why VCs are favoring CIGS? The choice of VCs may perhaps be simply indicative of the preferences of private equity investors. The highest amount of private equity investment in thin films has gone into CdTe, most likely because it is an established technology and has been proven in production on a large scale[14]. CIGS, on the other hand does not have much current production, as shown in Figure 4.

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[10] *See* Hari Polavarapu, *Solar Photovoltaics*, DEUTSCHE BANK SECURITIES REPORT (2007).

[11] *See* Michael Powalla, et al., *Scaling Up Issues of CIGS Solar Cells*, 361-362 THIN SOLID FILMS (2001).

[12] *See* Kenji Yamamoto, et al., *Cost Effective and High-Performance Thin Film Si Solar Cell Towards the 21st Century*, 66 SOLAR ENERGY MATERIALS & SOLAR CELLS (2001).

[13] *See* Wilfried van Sark, et al., *Analysis of the Silicon Market: Will Thin Films Profit?*, 10 ENERGY POLICY (2007).

[14] *See* Mike Cooke, *CdTe PV Progresses to Mass Production*, 3 SEMICONDUCTOR TODAY (2008).

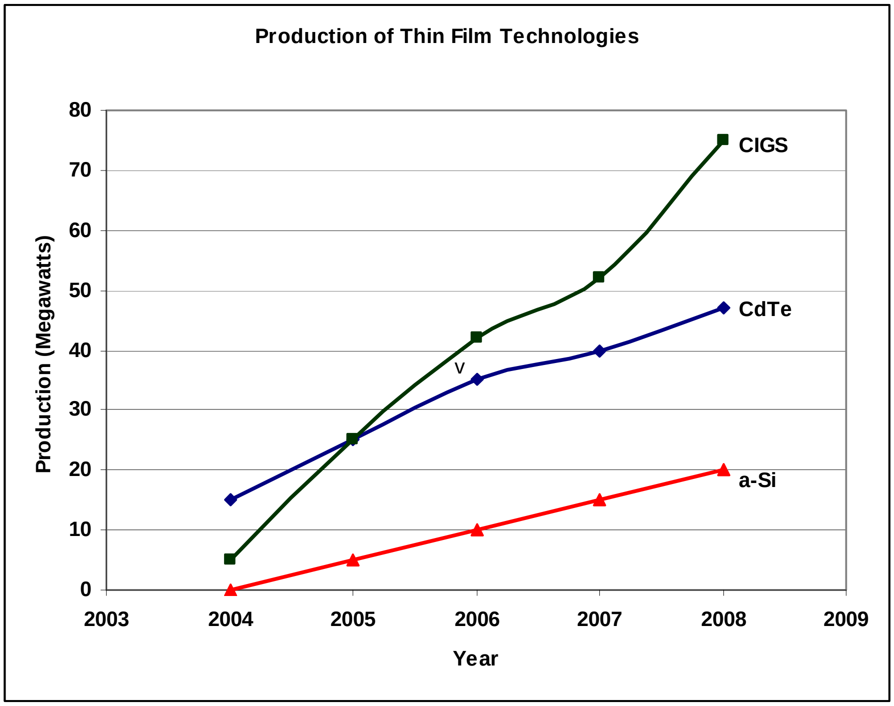

Figure 4
Notes: Most of current production uses a-Si or CdTe.

With most of the private equity investors directing their investments towards the more established CdTe technology, CIGS companies would find it difficult to attract private equity investment. The remaining option available for financing for CIGS firms is through VCs, and that might explain the huge VC investments in CIGS relative to CdTe and a-Si.

The above analysis also points to a potential adverse impact of the government policy of offering per unit subsidies to solar technologies. Although VCs seems to think that CIGS has the best long term potential, the government policy of offering per unit subsidies implies that most of the current government investment is going into CdTe and a-Si. This points to a need to focus government investment into solar energy based on future potential as opposed to current dominance.

V. CONCLUSION

Among the three thin film solar technologies, VC investment into CIGS far outweighs those into CdTe and a-Si. This is despite the fact that CdTe offers the lowest cost per watt and is projected to do so for many more years. VC choices might be guided by conversion efficiency, since CIGS offers the highest conversion efficiency among the three and is projected to remain so. The choice of VCs points to a potential perverse implication of current government policy. Since a main form of government support into solar industry is using per unit subsidies, the bulk of the government support is garnered by CdTe and a-Si firms, which currently occupy a much larger share of the solar market than CIGS. If VCs are making the right choices, then it implies that the government is favoring technologies that are currently superior, over technologies that have a better prospect over the longer term.